

MASTER OF SCIENCE IN MECHANICAL ENGINEERING

PRELIMINARY DESIGN STUDY OF AN ENHANCED MIXING EDUCTOR SYSTEM FOR THE LANDING, HELICOPTER ASSAULT SHIP REPLACEMENT GAS TURBINE EXHAUST

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A preliminary design study was conducted to determine the geometry for an enhanced mixing eductor system for the Landing, Helicopter Assault Ship Replacement (LHA (R)) program gas turbine exhaust. A one-dimensional analytical model, with a correction factor applied to the secondary mass flow, was developed to predict the secondary air mass flow rate and the exhaust temperature at the mixing tube exit plane. The resultant design consisted of a high aspect ratio lobed nozzle and a mixing tube. The model was also used to predict the backpressure developed by the ducting configuration. The proposed design resulted in a 50% reduction in exhaust temperature with only a six inch H₂O increase in backpressure. A detailed design of the oval-to-rectangular transition duct is provided, based on empirical data from a similar duct design. The study also included a prediction of plume radiation intensity in the 3-5 μm band for various aspect ratio slots.

KEYWORDS: Eductor, Enhanced Mixing, Lobed Mixer, Gas Turbine Exhaust, Plume Radiation

WAVE MAKING RESISTANCE CHARACTERISTICS OF TRIMARAN HULLS

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Recently, there has been an increased demand for high-speed vessels for both military and commercial applications. Many navies are exploring the potential of novel hull forms as part of efforts to achieve transformation in both combat and logistics missions in littoral seas. This demand for high-speed vessels has resulted in a need for unconventional hull forms in order to balance speed with payload requirements. One such hull form is the trimaran. The purpose of this thesis is to investigate the effects of side hull position on the wave making resistance characteristics of powered trimarans. Resistance calculations were performed by a three dimensional, Rankine panel code. A systematic series of runs was conducted in order to classify ship resistance in terms of major trimaran hull geometric configurations. The results of this thesis can be directly utilized in design, in order to minimize ship resistance and maximize available payload.

KEYWORDS: High-Speed Vessels, Littoral, Unconventional Hull Forms, Side Hull, Trimaran, Rankine Panel Code, Resistance, Payload

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SENSITIVITY ANALYSIS OF THE SEAKEEPING BEHAVIOR OF TRIMARAN SHIPS

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The dynamic response of the ship while operating in different sea conditions is one of the design parameters of a hull form. The objective of this thesis is to analyze the seakeeping response of trimaran hulls. A three-dimensional Rankine source panel method is used to achieve that. Seakeeping response characteristics of a typical trimaran with a variable separation ratio (the ratio of the lateral distance between center hull and side hull to the length of the ship) and with different longitudinal positions of the side hulls are analyzed. Heave and pitch motion response amplitude operators are evaluated for bow, bow quartering, and beam waves in irregular seas at various ship forward speeds. The corresponding heave and pitch responses were calculated by applying the Bretschneider spectral formulation. Seakeeping behaviors of the generic trimaran are classified based on the plots of root mean square values for every position of the side hulls at different sea states to determine optimal location of the side hulls with regard to seakeeping.

KEYWORDS: Seakeeping, Ship Response Spectrum, Trimaran Hull Form, SWAN2, Root Mean Square, Response Amplitude Operator

MOLECULAR DYNAMICS SIMULATION OF FATIGUE DAMAGE IN METALS

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Molecular dynamics simulation was conducted to better understand the mechanism of fatigue failure and to identify a parameter(s) that can indicate progressive damage due to cyclic loading. The Embedded Atom Method (EAM) was used for copper atoms subjected to cyclic loadings. Defective crystal structures including vacancies or impurities were considered for the study. The results showed that there was an increase in potential energy and kinetic energy, respectively, in the metal as the number of cycles increased. This means the metal becomes weaker, i.e., an indication of progressive damage. Therefore, the change of potential energy may be used as an indicator for fatigue damage accumulation. Furthermore, the relative distances between vacancies (or impurities) increased globally with fluctuation as the number of loading-unloading cycles increased.

KEYWORDS: Metals, Fracture, Mechanical Properties

FIN STABILIZERS AS MANEUVER CONTROL SURFACES

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Roll angle is often a limiting factor during high-speed turns and repetitive turning maneuvers. Navy and Coast Guard surface ships are designed for high-speed operation. Sharper turns at higher speeds and repetitive high-speed turns can increase ship survivability by helping these vessels avoid incoming threats. This is particularly true if the amount and direction of roll during the turn is controlled, since the ship's susceptibility to radar and other sensors may be diminished at certain angles. Sharper turns at higher speeds can also reduce the time it takes to reach a person in the water, improving the chances for successful rescue. Controlled roll during repetitive sharp turns can make high-speed pursuit safer and more likely to succeed. The objective of this thesis is to study the effects of fin stabilizers on a ship's turning

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performance. Fin stabilizers, commonly added to a ship design for the sole purpose of minimizing unwanted roll during ordinary operations, are also shown to favorably influence both the magnitude and direction of heel experienced during high speed and repetitive maneuvers. The effects of fin stabilizers on other turn performance characteristics are also examined. A strategy for actively employing fins during maneuvers is proposed.

KEYWORDS: Surface Ship, Fin Stabilizers, Maneuver, Roll, Turning

AN EMPIRICAL STUDY OF A PIN-FIN HEAT EXCHANGER IN LAMINAR AND TURBULENT FLOW

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This study concentrates on the empirical characterization of a staggered array pin-fin compact heat exchanger placed in a modular, rectangular wind tunnel. A full analysis of the heat transfer and pressure drop behavior was conducted on various pin-fin shapes, sizes, and configurations. The study was based on airflow over a range of low Reynolds numbers in the laminar and low turbulent flow, as well as higher turbulent flow regimes. The empirical data gathered can be used to corroborate and develop better numerical models to characterize the performance of such compact heat exchangers.

KEYWORDS: Compact Heat Exchanger, Experimental Study, Pin-Fin Array

HORIZONTAL STEERING CONTROL IN DOCKING THE *ARIES* AUV

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To keep the operational cost down and increase the mission time with minimum human intervention, autonomous recovery or docking operation of an Autonomous Underwater Vehicle (AUV) is required. Central to the successful autonomous docking process of the AUV is the capability of the AUV to track and steer itself accurately towards the dock, which is constantly perturbed by wave motion effects. In addition, for accurate acoustic homing during the final stages of the docking, the AUV requires acoustic systems with high update rates. Equipped with acoustic modem, *ARIES* had experimentally been tested to have an update rate of only about 0.3 Hz. These delayed data can potentially cause a false commanded reference input to the tracking system in between the updates and cause *ARIES* to miss the moving cage's entrance.

This thesis attempts to investigate the effectiveness of the use of cross track error and line-of-sight error sliding mode controller coupled with dynamic waypoints allocation in horizontal steering of *ARIES* in docking operations. In the absence of cage heading updates, a predictive method based on angular rate and direction of motion was used to estimate the dynamics of the moving cage. Further analysis was performed in order to understand the limitations of such an implementation.

KEYWORDS: Sliding Mode Control, Waypoint Navigation, Docking of AUV

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EXPERIMENTAL AND NUMERICAL ANALYSIS OF A CROSSFLOW FAN

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An auto vehicle that can take off and land vertically is envisioned to solve current and future problems of road congestion by utilizing the enormous air space above us. In the past, a crossflow fan was considered to serve this purpose, but its capability is not sufficient to provide enough vertical thrust with limited power and space. Hence, more in depth study is required to further improve the thrust efficiency and thrust to power ratio to a point where this thrust producing method is viable.

A 12-inch diameter, 1.5-inch span, 30-blade crossflow fan test apparatus was constructed and tested using an existing Turbine Test Rig as a power source. Instrumentation was installed and a data acquisition program was developed to measure the performance of the crossflow fan. Performance measurement was taken over a speed range of 1,000 to 6,000 RPM.

An experiment was conducted with the crossflow fan to determine, among other things, the stalling characteristics of the compressor. Performance and flow visualization results were compared to predictions obtained from a 2-D numerical simulation conducted using Flo++, a commercial PC-based computational fluid dynamics software package by Softflo.

KEYWORDS: Crossflow Fan, VTOL, Experiment, Numerical Simulation